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PTO/SB/05 (2/98)
Approved for use through 09/30/00. OMB 0651-0032
Patent and Trademark Office: U.S. DEPARTMENT OF COMMERCE

UTILITY PATENT APPLICATION TRANSMITTAL

(Only for new nonprovisional applications under 37 CFR 1.53(b))

Attorney Docket No.	25821.P028
First Inventor or Application Identifier	Steve W.L. Yeung
Title	AN EFFICIENT LIQUID CRYSTAL DISPLAY DRIVING SCHEME USING
Express Mail Label No.	

APPLICATION ELEMENTS
See MPEP chapter 600 concerning utility patent application contents

ADDRESS TO: Assistant Commissioner for Patents
Box Patent Application
Washington, DC 20231

1. [X] Fee Transmittal Form (e.g. PTO/SB/17)
   (Submit an original, and a duplicate for fee processing)
2. [ ] Specification — Total Pages [ ]
   (preferred arrangement set forth below)
   - Descriptive title of the Invention
   - Cross References to Related Applications
   - Statement Regarding Fed sponsored R & D
   - Reference to Microfiche Appendix
   - Background of the Invention
   - Brief Summary of the Invention
   - Brief Description of the Drawings (if filed)
   - Detailed Description
   - Claim(s)
   - Abstract of the Disclosure
3. [ ] Drawing(s) (35 U.S.C.113) — Total Sheets [ ]
4. Oath or Declaration — Total Pages [ ]
   a. [ ] Newly executed (original copy)
   b. [ ] Copy from a prior application (37 CFR 1.63(d))
   (for continuation/divisional with Box 16 completed)
   i. [ ] DELETION OF INVENTOR(S)
   Signed statement attached deleting inventor(s) named in the prior application, see 37 CFR 1.63(d)(2) and 1.33(b).

*NOTE FOR ITEMS 1 & 13: IN ORDER TO BE ENTITLED TO PAY SMALL ENTITY FEES, A SMALL ENTITY STATEMENT IS REQUIRED (37 C.F.R. § 1.27), EXCEPT IF ONE FILED IN A PRIOR APPLICATION IS RELIED UPON (37 C.F.R. § 1.28).

5. [ ] Microfiche Computer Program (Appendix)
6. Nucleotide and/or Amino Acid Sequence Submission
   (if applicable, all necessary)
   a. [ ] Computer Readable Copy
   b. [ ] Paper Copy (identical to computer copy)
   c. [ ] Statement verifying identity of above copies

ACCOMPANYING APPLICATION PARTS

7. [ ] Assignment Papers (cover sheet & document(s))
8. [ ] 37 CFR 3.73(b) Statement (when there is an assignee) [ ] Power of Attorney
9. [ ] English Translation Document (if applicable)
10. [ ] Information Disclosure Statement (IDS)/PTO - 1449 [ ] Copies of IDS Citations
11. [ ] Preliminary Amendment
12. [ ] Return Receipt Postcard (MPEP 503)
    (Should be specifically itemized)
13. [ ] *Small Entity Statement(s) [ ] Statement filed in prior application, Status still proper and desired
14. [ ] Certified Copy of Priority Document(s)
    (if foreign priority is claimed)
15. [ ] Other: . . . .

16. If a CONTINUING APPLICATION, check appropriate box, and supply the requisite information below and in a preliminary amendment:

[ ] Continuation [ ] Divisional [ ] Continuation-in-part (CIP) of prior application No:_____/__________

Prior application Information: Examiner__________ Group/Art Unit:__________

For CONTINUATION or DIVISIONAL APPS only: The entire disclosure of the prior application, from which an oath or declaration is supplied under Box 4b, is considered a part of the disclosure of the accompanying continuation or divisional application and is hereby incorporated by reference. The incorporation can only be relied upon when a portion has been inadvertently omitted from the submitted application parts.

17. CORRESPONDENCE ADDRESS

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Signature	[signature]	Date	10/2/2000

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FEE TRANSMITTAL

Patent fees are subject to annual revision on October 1. These are the fees effective October 1, 1997. Small Entity payments must be supported be a small entity statement, otherwise large entity fees must be paid. See Forms PTO/SB/09-12. See 37 C.F.R. §§ 1.28 and 1.28

TOTAL AMOUNT OF PAYMENT ($) 710.00

Complete if Known	
Application Number	
Filing Date	
First Named Inventor	Steve W.L. Yeung, et al.
Examiner Name	
Group Art Unit	
Attorney Docket Number	25821.P028

METHOD OF PAYMENT (check one)

1. ☒ The Commissioner is hereby authorized to charge indicated fees and credit any over payments to:

Deposit Account Number: 02-2666

Deposit Account Name: Blakely, Sokoloff, Taylor & Zafman LLP

☒ Charge Any Additional Fee Required Under 37 CFR 1.16 and 1.17
☐ Charge the Issue Fee Set in 37 CFR 1.18 at the Mailing of the Notice of Allowance.

2. ☐ Payment Enclosed:
☐ Check ☐ Money Order ☐ Other

FEE CALCULATION (fees effective 10/01/96)

1. FILING FEE

Large Entity Fee Code	Large Entity Fee ($)	Small Entity Fee Code	Small Entity Fee ($)	Fee Description	Fee Paid
101	690	201	345	Utility filing fee	710
106	310	206	155	Design filing fee	
107	480	207	240	Plant filing fee	
108	690	208	345	Reissue filing fee	
114	150	214	75	Provisional filing fee	

SUBTOTAL (1) ($) 710.00

2. EXTRA CLAIM FEES

			Extra Claims		Fee from below		Fee Paid
Total Claims	13	-20** =	0	X		=	0.00
Independent Claims	1	-3** =	0	X		=	0.00
Multiple Dependent						=	

***or number of previously paid, if greater; For Reissues, see below*

Large Entity Fee Code	Large Entity Fee ($)	Small Entity Fee Code	Small Entity Fee ($)	Fee Description
103	18	203	9	Claims in excess of 20
102	78	202	39	Independent claims in excess of 3
104	270	204	135	Multiple Dependent claim
109	78	209	39	**Reissue independent claims over original patent
110	18	210	9	**Reissue claims in excess of 20 and over original patent

SUBTOTAL (2) ($) 0.00

FEE CALCULATION (continued)

3. ADDITIONAL FEE

Large Entity Fee Code	Large Entity Fee ($)	Small Entity Fee Code	Small Entity Fee ($)	Fee Description	Fee Paid
105	130	205	65	Surcharge - late filing fee or oath	
127	50	227	25	Surcharge - late provisional filing fee or cover sheet.	
139	130	139	130	Non-English specification	
147	2,520	147	2,520	For filing a request for reexamination	
112	920*	112	920*	Requesting publication of SIR prior to Examiner action	
113	1,840*	113	1,840*	Requesting publication of SIR after Examiner action	
115	110	215	55	Extension for response within first month	
116	380	216	190	Extension for response within second month	
117	870	217	435	Extension for response within third month	
118	1,360	218	680	Extension for response within fourth month	
128	1,850	228	925	Extension for response within fifth month	
119	300	219	150	Notice of Appeal	
120	300	220	150	Filing a brief in support of an appeal	
121	260	221	130	Request for oral hearing	
138	1,360	138	1,360	Petition to institute a public use proceeding	
140	110	240	55	Petition to revive - unavoidably	
141	1,210	241	605	Petition to revive - unintentionally	
142	1,210	242	605	Utility issue fee (or reissue)	
143	430	243	215	Design issue fee	
144	580	244	290	Plant issue fee	
122	130	122	130	Petitions to the Commissioner	
123	50	123	50	Petitions related to provisional applications	
126	240	126	240	Submission of Information Disclosure Stmt	
581	40	581	40	Recording each patent assignment per property (times number of properties)	
146	760	246	380	Filing a submission after final rejection (37 CFR 1.129(a))	
149	760	249	380	For each additional invention to be examined (37 CFR 1.129(b))	

Other fee (specify) ____________
Other fee (specify) ____________

* Reduced by Basic Filing Fee Paid

SUBTOTAL (3) ($)

SUBMITTED BY				Complete (if applicable)	
Typed or Printed Name	Eric S. Hyman, Reg. No. 30,139			Reg. Number	
Signature	[signature]	Date	1/21/2000	Deposit Account User ID	02-2666

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AN EFFICIENT LIQUID CRYSTAL DISPLAY DRIVING SCHEME USING ORTHOGONAL BLOCK-CIRCULANT MATRIX

The invention relates to a protocol for driving a liquid crystal display, particularly to a driving scheme of liquid crystal display, and more particularly to a special arrangement of the entries of the driving matrix, which results in an efficient implementation of the scheme and a reduction in hardware complexity.

Passive matrix driving scheme is commonly adopted for driving a liquid crystal display. For those high-mux displays with liquid crystals of fast response, the problem of loss of contrast due to frame response is severe. To cope with this problem, active addressing was proposed in which an orthogonal matrix is used as the common driving signal. However, the method suffers from the problem of high computation and memory burden. Even worse, the difference in sequencies of the rows of matrix results in different row signal frequencies. This may result in severe crosstalk problems. On the other hand. Multi-Line-Addressing (MLA) was proposed, which makes a compromise between frame response, sequency, and computation problems. The block-diagonal driving matrix is made up of lower order orthogonal matrices. To further suppress the frame response, column interchanges of the driving matrix were suggested in such a way that the selections are evenly distributed among the frame. The complexity of the scheme is proportional to square of the order of the building matrix. Increase of order of the scheme results in complexity increase in both time and spatial domains. The order

increase asks for more logic hardware and voltage levels of the column signal.

According to the invention there is provided a protocol for driving a liquid crystal display, characterised in that a row (common) driving matrix consists of orthogonal block-circulant matrices.

Liquid Crystal Driving Scheme Using Orthogonal Block-Circulant Matrix

The following shows an order-8 Hadamard matrix.

$$\begin{bmatrix} 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 \\ 1 & -1 & 1 & -1 & 1 & -1 & 1 & -1 \\ 1 & 1 & -1 & -1 & 1 & 1 & -1 & -1 \\ 1 & -1 & -1 & 1 & 1 & -1 & -1 & 1 \\ 1 & 1 & 1 & 1 & -1 & -1 & -1 & -1 \\ 1 & -1 & 1 & -1 & -1 & 1 & -1 & 1 \\ 1 & 1 & -1 & -1 & -1 & -1 & 1 & 1 \\ 1 & -1 & -1 & 1 & -1 & 1 & 1 & -1 \end{bmatrix}$$

As mentioned in the foregoing, because of the computation burden and sequency problem of using active driving, MLA was proposed. To implement an 8-way drive by using 4-line MLA, two order-4 Hadamard matrices are used as the diagonal building blocks of the 8x8 driving matrix. The resulting common driving matrix is as follows:

$$\begin{bmatrix} 1 & 1 & 1 & 1 & 0 & 0 & 0 & 0 \\ 1 & -1 & 1 & -1 & 0 & 0 & 0 & 0 \\ 1 & 1 & -1 & -1 & 0 & 0 & 0 & 0 \\ 1 & -1 & -1 & 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 1 & 1 & 1 \\ 0 & 0 & 0 & 0 & 1 & -1 & 1 & -1 \\ 0 & 0 & 0 & 0 & 1 & 1 & -1 & -1 \\ 0 & 0 & 0 & 0 & 1 & -1 & -1 & 1 \end{bmatrix}$$

To minimize the sequency problem, another 4x4 orthogonal building block has been proposed. The resulting row (common) driving matrix is as follows:

$$\begin{bmatrix} -1 & 1 & 1 & 1 & 0 & 0 & 0 & 0 \\ 1 & 1 & -1 & 1 & 0 & 0 & 0 & 0 \\ 1 & -1 & 1 & 1 & 0 & 0 & 0 & 0 \\ 1 & 1 & 1 & -1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & -1 & 1 & 1 & 1 \\ 0 & 0 & 0 & 0 & 1 & 1 & -1 & 1 \\ 0 & 0 & 0 & 0 & 1 & -1 & 1 & 1 \\ 0 & 0 & 0 & 0 & 1 & 1 & 1 & -1 \end{bmatrix}$$

A general m-way display will have a mxm block diagonal orthogonal driving matrix made up of $m/4$ (assuming that m is an integer multiple of 4) 4x4 building blocks. The actual voltage applied is not necessary ± 1 but a constant multiple of the value (i.e., $\pm k$). To further suppress the frame response, it has been proposed that column interchanges of the row (common) driving matrix such that the selections are evenly distributed among the frame. Using the 8-way drive as example, the following row (common) driving matrix results:

$$\begin{bmatrix} -1 & 0 & 1 & 0 & 1 & 0 & 1 & 0 \\ 1 & 0 & 1 & 0 & -1 & 0 & 1 & 0 \\ 1 & 0 & -1 & 0 & 1 & 0 & 1 & 0 \\ 1 & 0 & 1 & 0 & 1 & 0 & -1 & 0 \\ 0 & -1 & 0 & 1 & 0 & 1 & 0 & 1 \\ 0 & 1 & 0 & 1 & 0 & -1 & 0 & 1 \\ 0 & 1 & 0 & -1 & 0 & 1 & 0 & 1 \\ 0 & 1 & 0 & 1 & 0 & 1 & 0 & -1 \end{bmatrix}$$

In the invention, there is proposed a method of generating orthogonal block-circulant building blocks that result in reduced hardware complexity of the driving circuitry. First of all, an orthogonal block-circulant matric is defined as follows:

Definition: An NMxNM block-circulant matrix B consisting of N MxM building blocks $A_1, A_2, \ldots A_N$ is of the form

$$B=\begin{bmatrix} A_1 & A_2 & \cdots & A_N \\ A_N & A_1 & \cdots & A_{N-1} \\ \vdots & \vdots & \ddots & \vdots \\ A_2 & A_3 & A_N & A_1 \end{bmatrix}.$$

It is said to be an orthogonal block-circulant if $B^TB=BB^T=(NM)I_{NM}$

For example, the following 4x4 matrix is orthogonal block-circulant

In this case, N can be 2 or 4. If N=2, then each A_i is 2x2 matrix. If N=4, then each A_i is

$$\begin{bmatrix} -1 & 1 & 1 & 1 \\ 1 & -1 & 1 & 1 \\ 1 & 1 & -1 & 1 \\ 1 & 1 & 1 & -1 \end{bmatrix}$$

a scalar (1 or −1). The orthogonal block-circulant matrix can be used as the diagonal building block of a row (common) driving matrix. By proper column and row interchanges, the resulting driving matrix has a property that each row is a shifted version of preceding rows and can be implemented by using shift registers. The following shows the resulting 8-way drive using 4x4 orthogonal block-circulant matrix after suitable row and column interchanges.

$$\begin{bmatrix} -1 & 0 & 1 & 0 & 1 & 0 & 1 & 0 \\ 0 & -1 & 0 & 1 & 0 & 1 & 0 & 1 \\ 1 & 0 & -1 & 0 & 1 & 0 & 1 & 0 \\ 0 & 1 & 0 & -1 & 0 & 1 & 0 & 1 \\ 1 & 0 & 1 & 0 & -1 & 0 & 1 & 0 \\ 0 & 1 & 0 & 1 & 0 & -1 & 0 & 1 \\ 1 & 0 & 1 & 0 & 1 & 0 & -1 & 0 \\ 0 & 1 & 0 & 1 & 0 & 1 & 0 & -1 \end{bmatrix}$$

For higher order B, the choice of the order of sub-block A_i is limited. Some M might result in nonexistence of orthogonal block-circulant B. Let MN=6, then M, the order of sub-block, can be 1, 2, or 3. It can be shown that orthogonal block-circulant B can be achieved by M=2, 3, but not M=1. In general, given that MN is even, it can be shown that orthogonal block-circulant B always exists provided that $M \neq 1$. In the following, two means of generating orthogonal block-circulant matrices are proposed.

The first method is based on theory of *paraunitary* matrix but it by no means generates all orthogonal block-circulant matrices. The second method is a means to identify orthogonal block-circulant matrices by nonlinear programming. Theoretically, it can be used to generate all orthogonal block-circulant matrices.

Generation of Orthogonal Block-Circulant Matrix Using Paraunitary Matrix

Consider order $MxNM$ sub-matrix of B as follows:

$$E = [A_1 \quad A_2 \quad K \quad A_N]$$

Define nxn shift matrix $S_{n,m}$ as follows

$$S_{n,m} = \begin{bmatrix} 0 & I_{m \times m} \\ 0_{(n-m)\times(n-m)} & 0 \end{bmatrix}$$

A paraunitary matrix E of order $MxNM$ satisfies

(i) E is orthogonal. i.e.,

$$EE^T = I$$

(ii) E is orthogonal to its column shift by multiples of M. i.e.,

$$ES_{NM,iM}E^T = 0$$

for i = 1,2, ... ,N-1.

In general, paraunitary matrices can be represented in a cascade lattice form with rotational angles as parameters.

The following two are two example 2x4 paraunitary matrices.

$$E_1 = \begin{bmatrix} 1 & 1 & -1 & 1 \\ -1 & -1 & -1 & 1 \end{bmatrix}$$

$$E_2 = \begin{bmatrix} -1 & 1 & 1 & 1 \\ 1 & -1 & 1 & 1 \end{bmatrix}$$

We have the following property of paraunitary matrices:

Property: B generated by block-circulating paraunitary E is orthogonal.

Proof: Define nxn recurrent shift matrix $R_{n,m}$ as follows

An *orthogonal block-circulant* matrix B of order $NMxNM$ with $MxNM$ sub-matrix E satisfies

(i) E is orthogonal. i.e.,

$$EE^T = I$$

(ii) E is orthogonal to its recurrent shift by multiples of M. i.e.,

$$ER_{NM,iM}E^T = 0$$

for $i = 1,2, \ldots ,N$-1.

Provided that E is paraunitary, as

$$R_{n,m} = S_{n,m} + S^T_{n-m,n-m}$$

we have

$$ER_{(N-1)M,iM}E^T = E(S_{n,m} + S^T_{n-m,n-m})E^T = ES_{n,m}E^T + ES^T_{n-m,n-m}E^T = 0$$

and that completes the proof. Notice that E is paraunitary is a sufficient but not necessary condition for B to be orthogonal block-circulant. Using E_1 and E_2 as building blocks, we obtain the following orthogonal block-circulant matrices.

$$B_1 = \begin{bmatrix} 1 & 1 & -1 & 1 \\ -1 & -1 & -1 & 1 \\ -1 & 1 & 1 & 1 \\ -1 & 1 & -1 & -1 \end{bmatrix}$$

$$B_2 = \begin{bmatrix} -1 & 1 & 1 & 1 \\ 1 & -1 & 1 & 1 \\ 1 & 1 & -1 & 1 \\ 1 & 1 & 1 & -1 \end{bmatrix}$$

Notice that B_2 is orthogonal circulant as well as orthogonal block-circulant. As illustrated before, by using it as the building block of row (common) driving matrix with suitable row and column interchanges, each row is a delay-1 shifted version of preceding row. However, B_1 is orthogonal block-circulant but it is not circulant. By suitable row and column interchanges of the resulting driving matrix, two sets of row (common) driving waveforms are obtained. Within a set, each row is a shifted version of the others.

The complexity of implementation is proportional to the order of the sub-blocks A_i (i.e., M). For NM=4, we observe that M can be 1 or 2. For higher order, M=1 does not result in any circulant B that is orthogonal. Provided M=2, orthogonal block-circulant B always exists and can be generated by $2x2N$ paraunitary matrices. The driving matrix resulted from B_2 with suitable column interchanges is shown below:

$$\begin{bmatrix} 1 & 0 & 1 & 0 & -1 & 0 & 1 & 0 \\ -1 & 0 & -1 & 0 & -1 & 0 & 1 & 0 \\ -1 & 0 & 1 & 0 & 1 & 0 & 1 & 0 \\ -1 & 0 & 1 & 0 & -1 & 0 & -1 & 0 \\ 0 & 1 & 0 & 1 & 0 & -1 & 0 & 1 \\ 0 & -1 & 0 & -1 & 0 & -1 & 0 & 1 \\ 0 & -1 & 0 & 1 & 0 & 1 & 0 & 1 \\ 0 & -1 & 0 & 1 & 0 & -1 & 0 & -1 \end{bmatrix}$$

Rows 1, 3, 5, 7 and 2, 4, 6, 8 form the two sets within which each row is a shifted version of the others.

Generation of Orthogonal block-circulant Matrix by Nonlinear Programming

An orthogonal block-circulant matrix can be generated by nonlinear programming. The method of steepest descent illustrates this. The method of steepest descent is widely used in the identification of complex and nonlinear systems. The update law in identifying sub-matrix E can be stated as follows:

$$E_{n+1} = E_n + \delta \frac{\partial P}{\partial E}$$

where δ is the step size. P is the cost or penalty function. We set P as follows:

$$P(E) = \sum_{i,j} \left(e_{ij}^2 - 1\right)^2 + \left\| EE^T - I \right\|_F^2 + \sum_i \left\| E R_{\text{[illegible]}} E^T \right\|_F^2$$

e_{ij} are the entries of E. $\|\cdot\|_F$ is the Frobenius norm of a matrix. The first summation in the function forces all the entries of E to be ± 1. The second one forces E to be orthogonal, while the third summation ensures orthogonal block-circulant property of the resulting B.

List of Order-4 and Order-8 Orthogonal Block-Circulant Matrices

The following is an exhaustion of all 2x4 and 2x8 sub-matrices E with entries ± 1 that result in orthogonal block-circulant building block.

Order-4

(1)

$$\begin{bmatrix} 1 & 1 & -1 & 1 \\ 1 & 1 & 1 & -1 \end{bmatrix};$$

(2)

$$\begin{bmatrix} -1 & 1 & 1 & 1 \\ 1 & 1 & 1 & -1 \end{bmatrix};$$

(3)

$$\begin{bmatrix} -1 & 1 & -1 & -1 \\ 1 & 1 & -1 & 1 \end{bmatrix};$$

(4)

$$\begin{bmatrix} -1 & -1 & -1 & 1 \\ 1 & 1 & -1 & 1 \end{bmatrix};$$

(5) all alternatives of (1)-(4) generated by

(i) sign inversion (i.e., $-E$);
(ii) row interchange, i.e.,

$$\begin{bmatrix} 0 & 1 \\ 1 & 0 \end{bmatrix} E;$$

(iii) circulant shift of E, i.e.,

$$E R_{4,2}$$

and any combinations of (i)-(iii).

Order-8

(1)

$$\begin{bmatrix} 1 & 1 & -1 & 1 & 1 & -1 & 1 & 1 \\ 1 & 1 & 1 & -1 & 1 & -1 & -1 & -1 \end{bmatrix};$$

(2)

$$\begin{bmatrix} 1 & 1 & 1 & -1 & 1 & -1 & -1 & -1 \\ [illegible] \\ 1 & 1 & 1 & 1 & -1 & 1 & 1 & -1 \end{bmatrix};$$

(3)
(4)
(5)
(6)

$$\begin{bmatrix} 1 & 1 & -1 & 1 & -1 & 1 & -1 & -1 \\ [illegible] \\ [illegible] \\ [illegible] \\ 1 & 1 & 1 & 1 & -1 & 1 & 1 & -1 \end{bmatrix};$$

(7)

$$(8)\quad \begin{bmatrix} -1 & 1 & 1 & -1 & 1 & -1 & 1 & -1 \\ 1 & 1 & 1 & 1 & 1 & 1 & -1 & -1 \end{bmatrix};$$

$$(9)\quad \begin{bmatrix} -1 & 1 & 1 & 1 & 1 & 1 & 1 & -1 \\ 1 & 1 & -1 & 1 & -1 & 1 & -1 & -1 \end{bmatrix};$$

$$(10)\quad \begin{bmatrix} -1 & 1 & -1 & 1 & -1 & 1 & 1 & -1 \\ 1 & 1 & -1 & -1 & -1 & -1 & -1 & -1 \end{bmatrix};$$

$$(11)\quad \begin{bmatrix} -1 & 1 & 1 & -1 & -1 & -1 & -1 & -1 \\ 1 & 1 & -1 & 1 & -1 & 1 & -1 & -1 \end{bmatrix};$$

$$(12)\quad \begin{bmatrix} 1 & -1 & -1 & 1 & -1 & 1 & -1 & 1 \\ 1 & 1 & 1 & 1 & 1 & 1 & -1 & -1 \end{bmatrix};$$

$$(13)\quad \begin{bmatrix} 1 & -1 & -1 & 1 & 1 & -1 & 1 & -1 \\ 1 & 1 & 1 & 1 & 1 & 1 & -1 & -1 \end{bmatrix};$$

$$(14)\quad \begin{bmatrix} 1 & -1 & 1 & -1 & 1 & -1 & -1 & 1 \\ 1 & 1 & 1 & 1 & 1 & 1 & -1 & -1 \end{bmatrix};$$

$$(15)\quad \begin{bmatrix} 1 & -1 & -1 & 1 & -1 & -1 & -1 & -1 \\ 1 & 1 & 1 & -1 & 1 & -1 & -1 & -1 \end{bmatrix};$$

$$(16)\quad \begin{bmatrix} 1 & -1 & 1 & -1 & 1 & 1 & -1 & -1 \\ 1 & 1 & 1 & 1 & 1 & -1 & -1 & 1 \end{bmatrix};$$

$$(17)\quad \begin{bmatrix} 1 & -1 & 1 & 1 & 1 & 1 & -1 & 1 \\ 1 & 1 & 1 & -1 & 1 & -1 & -1 & -1 \end{bmatrix};$$

$$(18)\quad \begin{bmatrix} 1 & 1 & -1 & 1 & 1 & 1 & 1 & -1 \\ -1 & 1 & 1 & 1 & -1 & 1 & -1 & -1 \end{bmatrix};$$

(19)

$$\begin{bmatrix} 1 & 1 & 1 & -1 & 1 & 1 & -1 & 1 \\ -1 & 1 & 1 & 1 & -1 & 1 & -1 & -1 \end{bmatrix};$$

(20)

$$\begin{bmatrix} 1 & 1 & -1 & 1 & 1 & 1 & 1 & -1 \\ 1 & -1 & 1 & 1 & 1 & -1 & -1 & -1 \end{bmatrix};$$

(21)
(22)
(23)
(24)

$$\begin{bmatrix} -1 & 1 & 1 & 1 & 1 & -1 & 1 & 1 \\ \end{bmatrix};$$

[illegible]

$$\begin{bmatrix} -1 & 1 & 1 & 1 & -1 & 1 & -1 & -1 \end{bmatrix};$$

(25)
(26)
(27)

[illegible]

(28) all alternatives of (1)-(27) generated by

(i) sign inversion (i.e., $-E$);
(ii) row interchange, i.e.,

$$\begin{bmatrix} 0 & 1 \\ 1 & 0 \end{bmatrix} E;$$

(iii) circulant shift of E, i.e.,

$$ER_{8,2i}$$

i=1, 2, or 3, and any combinations of (i)-(iii)

Thus using the invention a special arrangement of the entries of driving matrix is proposed. By imposing orthogonal block-circulant property to the building blocks of the row (common) driving waveform, the row signals can be made to differ by time shifts only. Each row can now be implemented as a shifted version of preceding rows by using shift registers. The complexity of the matrix driving scheme is greatly reduced and is linearly proportional to the order of the orthogonal block-circulant building block.

WE CLAIM:

1. A protocol for driving a liquid crystal display, comprising:-
(i) a row (common) driving matrix; said matrix
(ii) consisting of orthogonal block-circulant matrices.

2. A protocol as defined in Claim 1, wherein there are row and column interchanges of said row (common) driving matrix.

3. A protocol as defined in Claim 1, wherein said row (common) driving matrix is an orthogonal block-circulant matrix.

4. A protocol as defined in Claim, wherein said row (common) driving matrix is a block diagonal matrix and wherein all the building blocks are orthogonal block-circulant.

5. A protocol as defined in Claim 4, wherein said row (common) driving matrix is a row and column interchanged version of the row (common) driving matrix.

6. A protocol as defined in Claim 1, wherein said row (common) driving matrix comprises orthogonal block-circulant building blocks generated by using a paraunitary matrix.

7. A protocol as defined in Claim 6, wherein said driving matrix is

$$\begin{bmatrix} 1 & 0 & 1 & 0 & -1 & 0 & 1 & 0 \\ -1 & 0 & -1 & 0 & -1 & 0 & 1 & 0 \\ -1 & 0 & 1 & 0 & 1 & 0 & 1 & 0 \\ -1 & 0 & 1 & 0 & -1 & 0 & -1 & 0 \\ 0 & 1 & 0 & 1 & 0 & -1 & 0 & 1 \\ 0 & -1 & 0 & -1 & 0 & -1 & 0 & 1 \\ 0 & -1 & 0 & 1 & 0 & 1 & 0 & 1 \\ 0 & -1 & 0 & 1 & 0 & -1 & 0 & -1 \end{bmatrix}$$

8. A protocol as defined in Claim 1, wherein said row (common) driving matrix is based on orthogonal block-circulant building blocks generated by nonlinear programming.

9. A protocol as defined in Claim 8, wherein said row (common) driving matrix is based on order-4 orthogonal block-circulant building blocks.

10. A protocol as defined in Claim 8, wherein said row (common) driving matrix is based on order-8 orthogonal block-circulant building blocks.

11. A protocol as defined in Claim 9, wherein said building blocks comprise

(1)

$$\begin{bmatrix} 1 & 1 & -1 & 1 \\ 1 & 1 & 1 & -1 \end{bmatrix};$$

(2)

$$\begin{bmatrix} -1 & 1 & 1 & 1 \\ 1 & 1 & 1 & -1 \end{bmatrix};$$

(3)

$$\begin{bmatrix} -1 & 1 & -1 & -1 \\ 1 & 1 & -1 & 1 \end{bmatrix};$$

(4)

$$\begin{bmatrix} -1 & -1 & -1 & 1 \\ 1 & 1 & -1 & 1 \end{bmatrix};$$

(5) all alternatives of (1)-(4) generated by

(i) sign inversion (i.e., $-E$);

(ii) row interchange, i.e.,

$$\begin{bmatrix} 0 & 1 \\ 1 & 0 \end{bmatrix} E;$$

(iii) circulant shift of E, i.e.,

$$ER_{4,2}$$

and any combinations of (i)-(iii).

12. A protocol as defined in Claim 10, wherein said building blocks comprise

(1)

$$\begin{bmatrix} 1 & 1 & -1 & 1 & 1 & -1 & 1 & 1 \\ 1 & 1 & 1 & -1 & 1 & -1 & -1 & -1 \end{bmatrix};$$

(2)

$$\begin{bmatrix} 1 & 1 & 1 & -1 & 1 & -1 & -1 & -1 \\ 1 & 1 & 1 & 1 & -1 & 1 & 1 & -1 \end{bmatrix};$$

(3)

$$\begin{bmatrix} 1 & 1 & -1 & -1 & -1 & 1 & -1 & -1 \\ 1 & 1 & 1 & 1 & -1 & 1 & 1 & -1 \end{bmatrix};$$

(4)

$$\begin{bmatrix} 1 & 1 & -1 & 1 & -1 & 1 & -1 & -1 \\ 1 & 1 & 1 & 1 & 1 & -1 & -1 & 1 \end{bmatrix};$$

(5)

$$\begin{bmatrix} -1 & 1 & -1 & 1 & 1 & -1 & -1 & 1 \\ 1 & 1 & 1 & 1 & 1 & 1 & -1 & -1 \end{bmatrix};$$

(6)

$$\begin{bmatrix} -1 & 1 & -1 & 1 & -1 & 1 & 1 & -1 \\ 1 & 1 & 1 & 1 & 1 & 1 & -1 & -1 \end{bmatrix};$$

(7)

$$\begin{bmatrix} -1 & 1 & -1 & 1 & 1 & 1 & -1 & -1 \\ 1 & 1 & 1 & 1 & -1 & 1 & 1 & -1 \end{bmatrix};$$

(8)

$$\begin{bmatrix} -1 & 1 & 1 & -1 & 1 & -1 & 1 & -1 \\ 1 & 1 & 1 & 1 & 1 & 1 & -1 & -1 \end{bmatrix};$$

(9)

$$\begin{bmatrix} -1 & 1 & 1 & 1 & 1 & 1 & 1 & -1 \\ 1 & 1 & -1 & 1 & -1 & 1 & -1 & -1 \end{bmatrix};$$

(10)

$$\begin{bmatrix} -1 & 1 & -1 & 1 & -1 & 1 & 1 & -1 \\ 1 & 1 & -1 & -1 & -1 & -1 & -1 & -1 \end{bmatrix};$$

(11)

$$\begin{bmatrix} -1 & 1 & 1 & -1 & -1 & -1 & -1 & -1 \\ 1 & 1 & -1 & 1 & -1 & 1 & -1 & -1 \end{bmatrix};$$

(12)

$$\begin{bmatrix} 1 & -1 & -1 & 1 & -1 & 1 & -1 & 1 \\ 1 & 1 & 1 & 1 & 1 & 1 & -1 & -1 \end{bmatrix};$$

(13)

$$\begin{bmatrix} 1 & -1 & -1 & 1 & 1 & -1 & 1 & -1 \\ 1 & 1 & 1 & 1 & 1 & 1 & -1 & -1 \end{bmatrix};$$

(14)

$$\begin{bmatrix} 1 & -1 & 1 & -1 & 1 & -1 & -1 & 1 \\ 1 & 1 & 1 & 1 & 1 & 1 & -1 & -1 \end{bmatrix};$$

(15)

$$\begin{bmatrix} 1 & -1 & -1 & 1 & -1 & -1 & -1 & -1 \\ 1 & 1 & 1 & -1 & 1 & -1 & -1 & -1 \end{bmatrix};$$

(16)

$$\begin{bmatrix} 1 & -1 & 1 & -1 & 1 & 1 & -1 & -1 \\ 1 & 1 & 1 & 1 & 1 & -1 & -1 & 1 \end{bmatrix};$$

(17)

$$\begin{bmatrix} 1 & -1 & 1 & 1 & 1 & 1 & -1 & 1 \\ 1 & 1 & 1 & -1 & 1 & -1 & -1 & -1 \end{bmatrix};$$

(18)

$$\begin{bmatrix} 1 & 1 & -1 & 1 & 1 & 1 & 1 & -1 \\ -1 & 1 & 1 & 1 & -1 & 1 & -1 & -1 \end{bmatrix};$$

(19)

$$\begin{bmatrix} 1 & 1 & 1 & -1 & 1 & 1 & -1 & 1 \\ -1 & 1 & 1 & 1 & -1 & 1 & -1 & -1 \end{bmatrix};$$

(20)

$$\begin{bmatrix} 1 & 1 & -1 & 1 & 1 & 1 & 1 & -1 \\ 1 & -1 & 1 & 1 & 1 & -1 & -1 & -1 \end{bmatrix};$$

(21)

$$\begin{bmatrix} 1 & 1 & 1 & -1 & 1 & 1 & -1 & 1 \\ 1 & -1 & 1 & 1 & 1 & -1 & -1 & -1 \end{bmatrix};$$

(22)

$$\begin{bmatrix} -1 & 1 & 1 & 1 & 1 & -1 & 1 & 1 \\ -1 & 1 & 1 & 1 & -1 & 1 & -1 & -1 \end{bmatrix};$$

(23)

$$\begin{bmatrix} -1 & -1 & -1 & 1 & 1 & -1 & -1 & -1 \\ 1 & 1 & -1 & 1 & -1 & 1 & -1 & -1 \end{bmatrix};$$

(24)

$$\begin{bmatrix} -1 & 1 & -1 & -1 & 1 & -1 & -1 & -1 \\ -1 & 1 & 1 & 1 & -1 & 1 & -1 & -1 \end{bmatrix};$$

(25)

$$\begin{bmatrix} 1 & -1 & 1 & 1 & -1 & 1 & 1 & 1 \\ -1 & 1 & 1 & 1 & -1 & 1 & -1 & -1 \end{bmatrix};$$

(26)

$$\begin{bmatrix} 1 & -1 & -1 & -1 & -1 & 1 & -1 & -1 \\ -1 & 1 & 1 & 1 & -1 & 1 & -1 & -1 \end{bmatrix};$$

(27)

$$\begin{bmatrix} 1 & -1 & 1 & -1 & 1 & 1 & -1 & -1 \\ -1 & 1 & 1 & -1 & -1 & -1 & -1 & -1 \end{bmatrix};$$

(28) all alternatives of (1)-(27) generated by

(i) sign inversion (i.e., $-E$);

(ii) row interchange, i.e.,

$$\begin{bmatrix} 0 & 1 \\ 1 & 0 \end{bmatrix} E;$$

(iii) circulant shift of E, i.e.,

$$ER_{8,2i}$$

i=1, 2, or 3, and any combinations of (i)-(iii)

13. A liquid crystal display, wherein there is a driving scheme, and a protocol as defined in Claim 1.

ABSTRACT OF THE DISCLOSURE

The invention relates to a protocol for driving a liquid crystal display, in which a row (common) matrix is made up of orthogonal block-circulant matrices which can be generated by nonlinear programming or alternatively by paraunitary matricing.